

Thermal Energy Grid Storage Using Multi-Junction Photovoltaics

Asegun Henry, MIT

**Team Members: Evelyn Wang, MIT; Myles Steiner, NREL;
Dan Friedman, NREL**

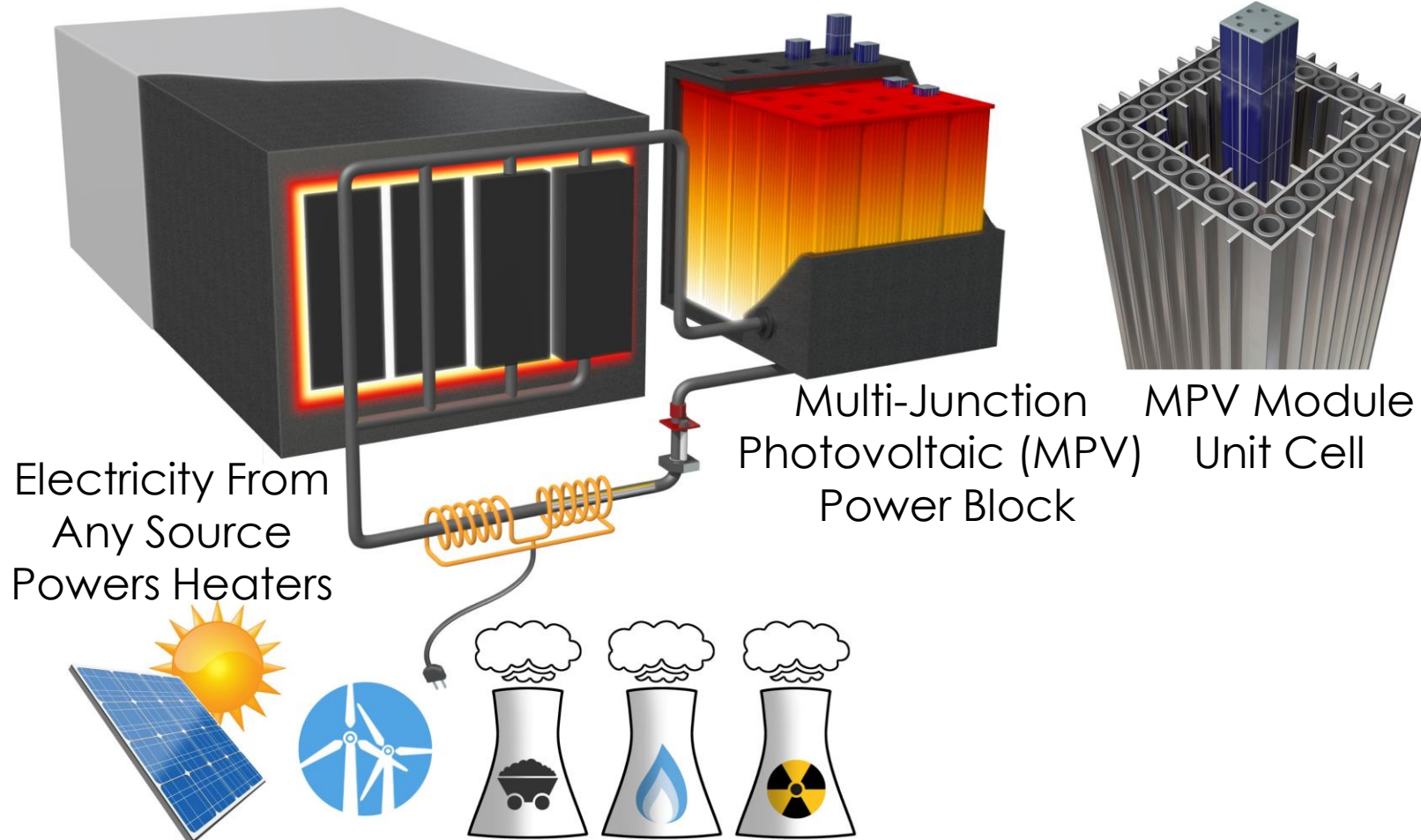
Project Vision

We're storing energy thermally to achieve low cost, while also storing the energy at extremely high temperature to enable low cost conversion using photovoltaics.

Total project cost:	\$1.5M
Current Q / Total Project Qs	Q8 / Q12

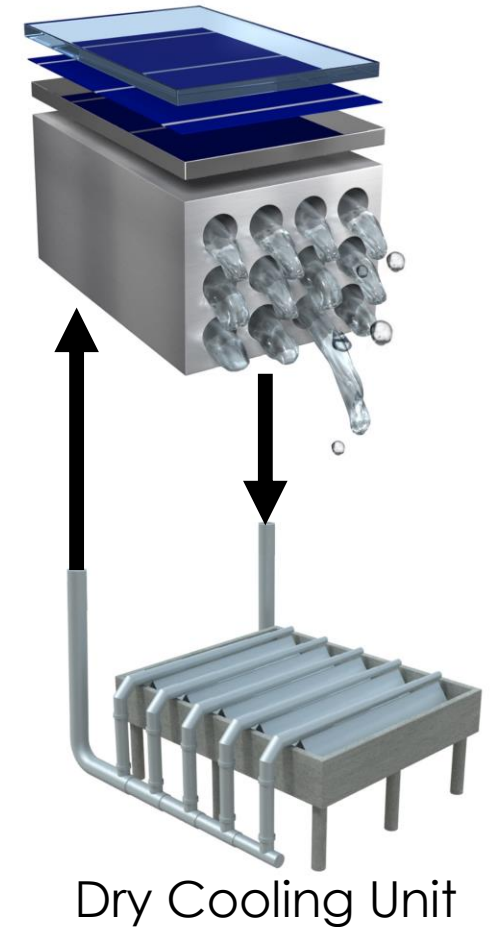
The Concept

Electricity → Heat → Electricity



C. Amy et al., Energy Environ. Sci., 12, 334-343 (2019)

Water Cooled MPV with Integrated Mirror

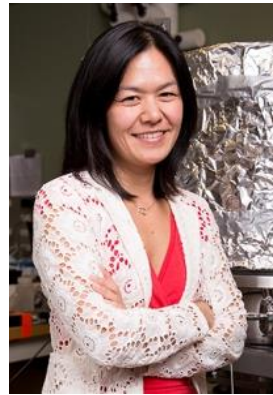


The Team

MIT :: Heat & Mass Transport and Storage



A. Henry



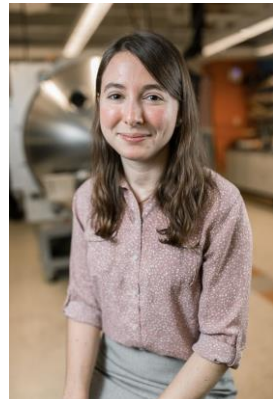
E. Wang



M. Pishahang



C. Kelsall



A. LaPotin



K. Buznistky

NREL :: Photon Conversion and Power Extraction



M. Steiner



D. Friedman

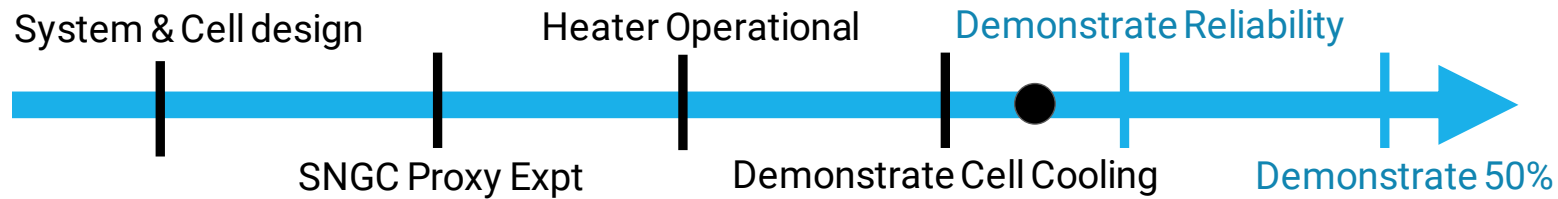


K. Schulte

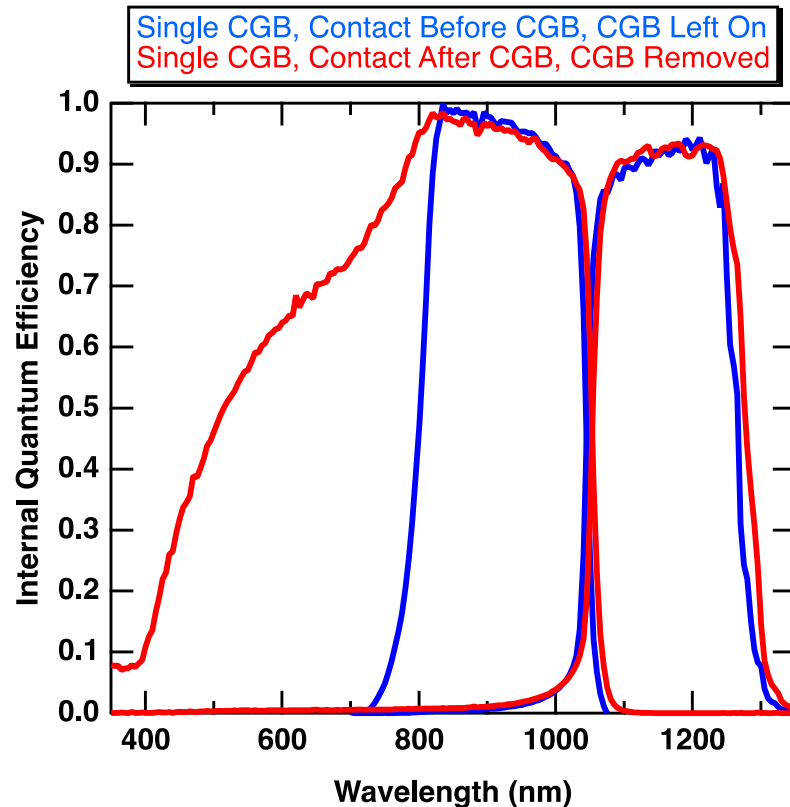


R. France

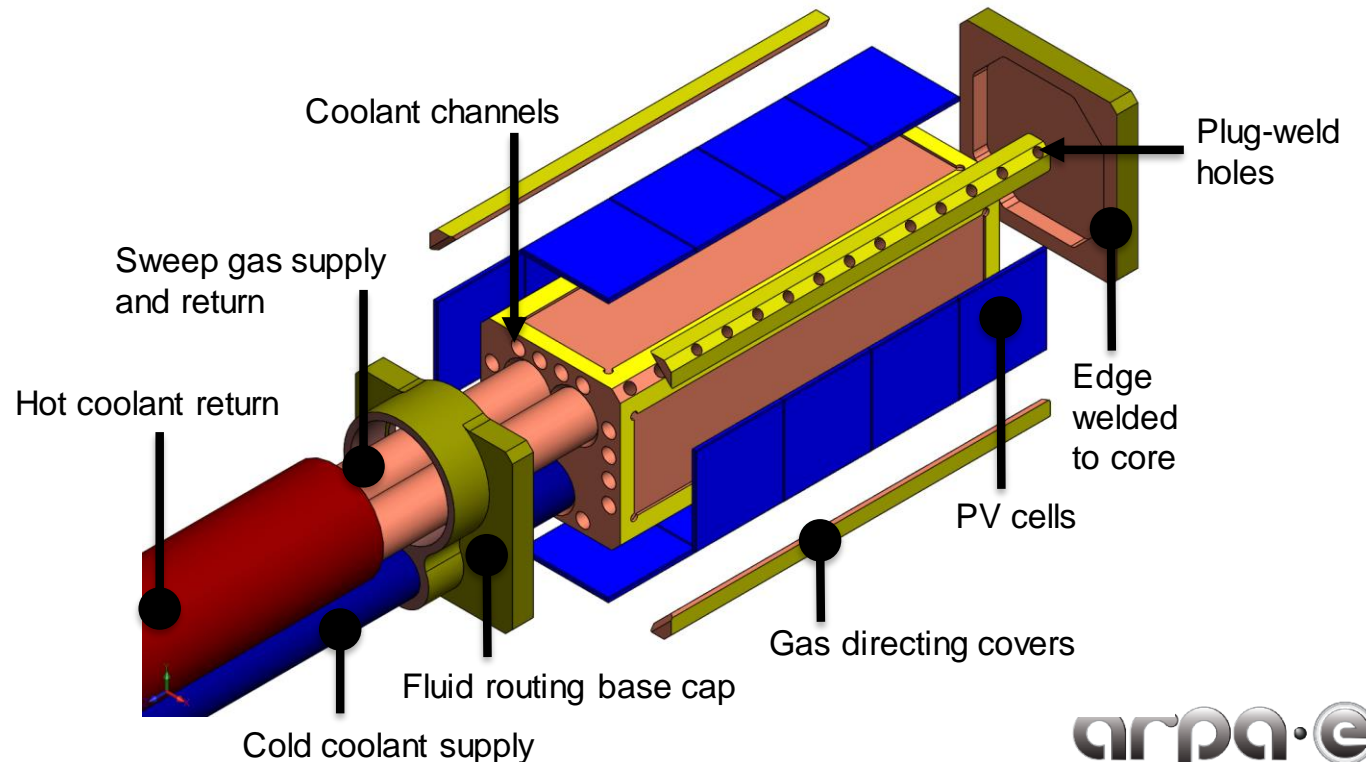
Project Objectives



[1] MPV Performance

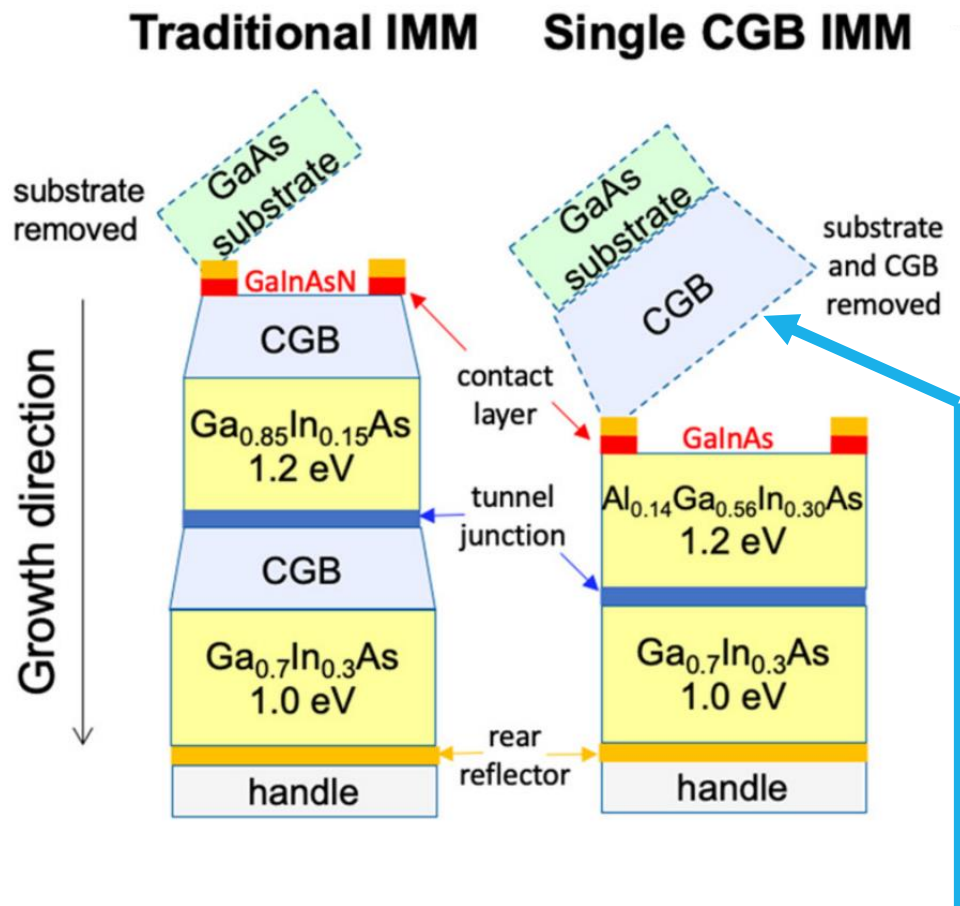


[2] MPV Cooling

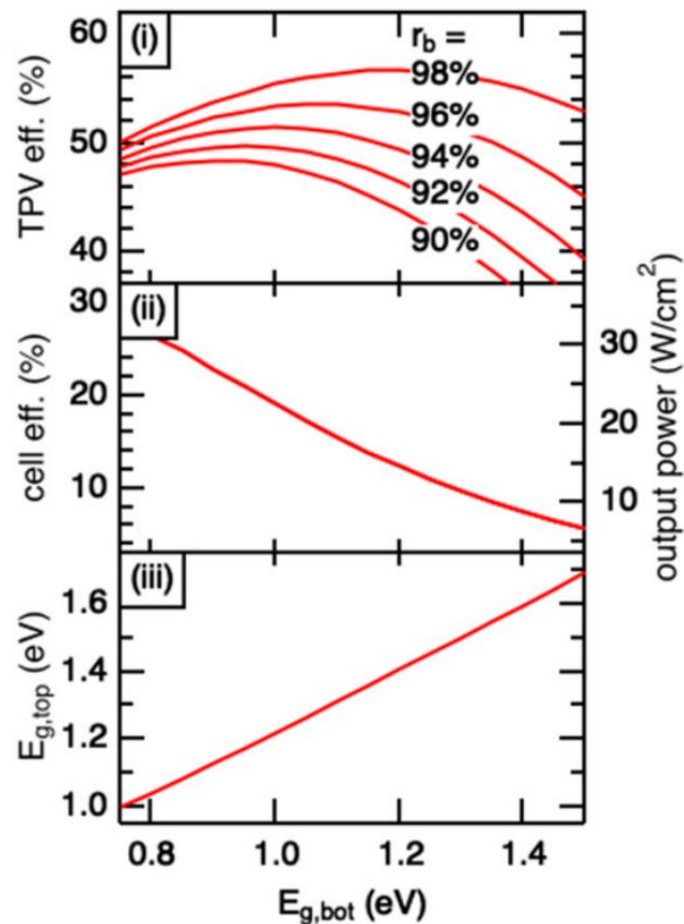


[3] MPV Reliability

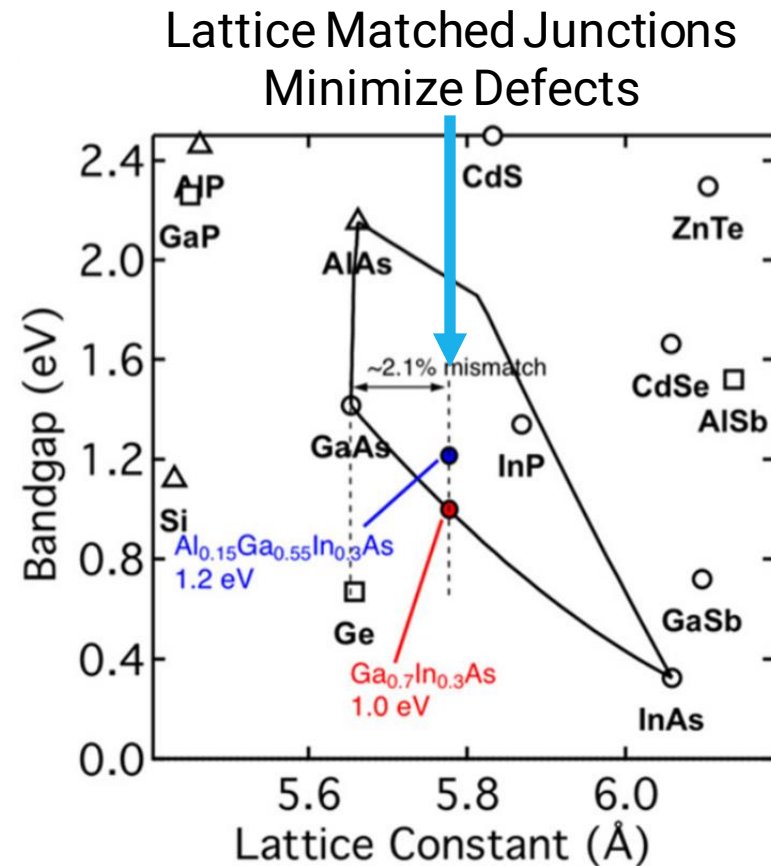
MPV Cell Efficiency



Compositionally Graded Buffer (CGB) Layer
Transitions Lattice Parameter
Removed to Minimize Sub-Band Gap Absorption

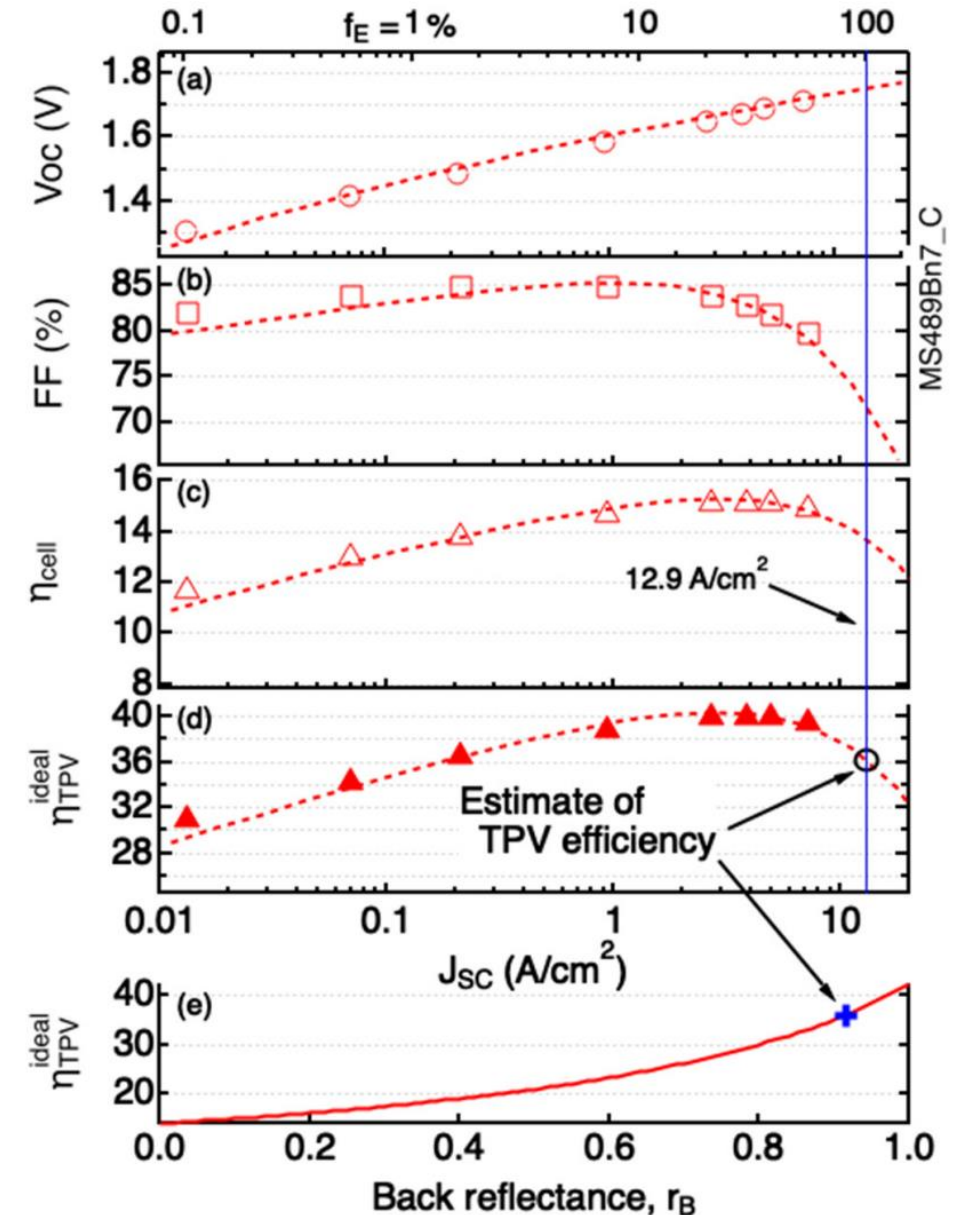
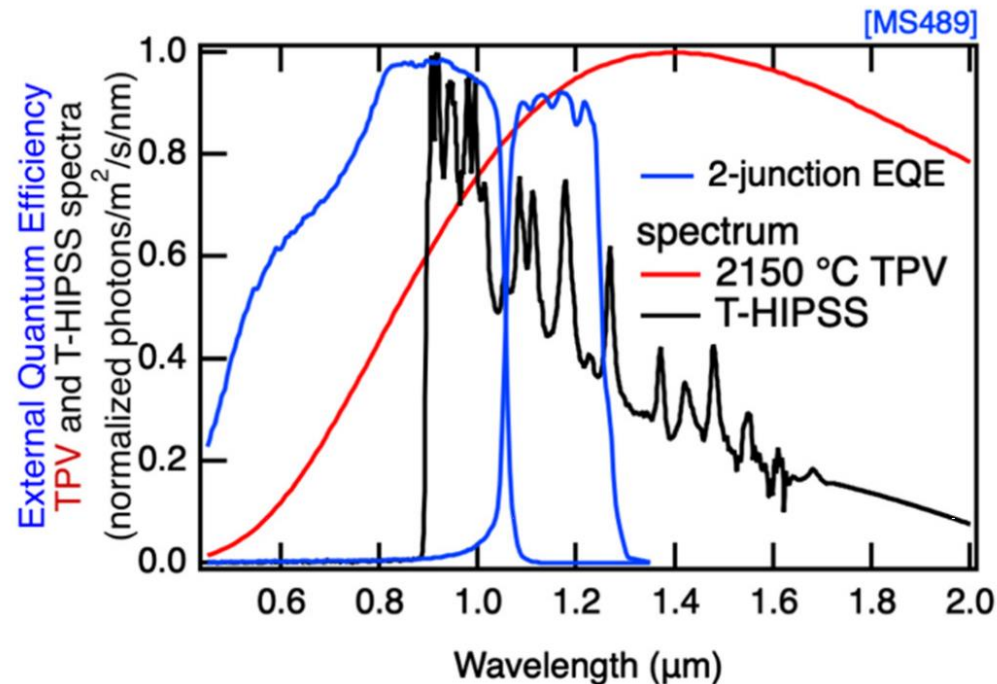


K. L. Schulte et al., Journal of Applied Physics 128, 143103 (2020)

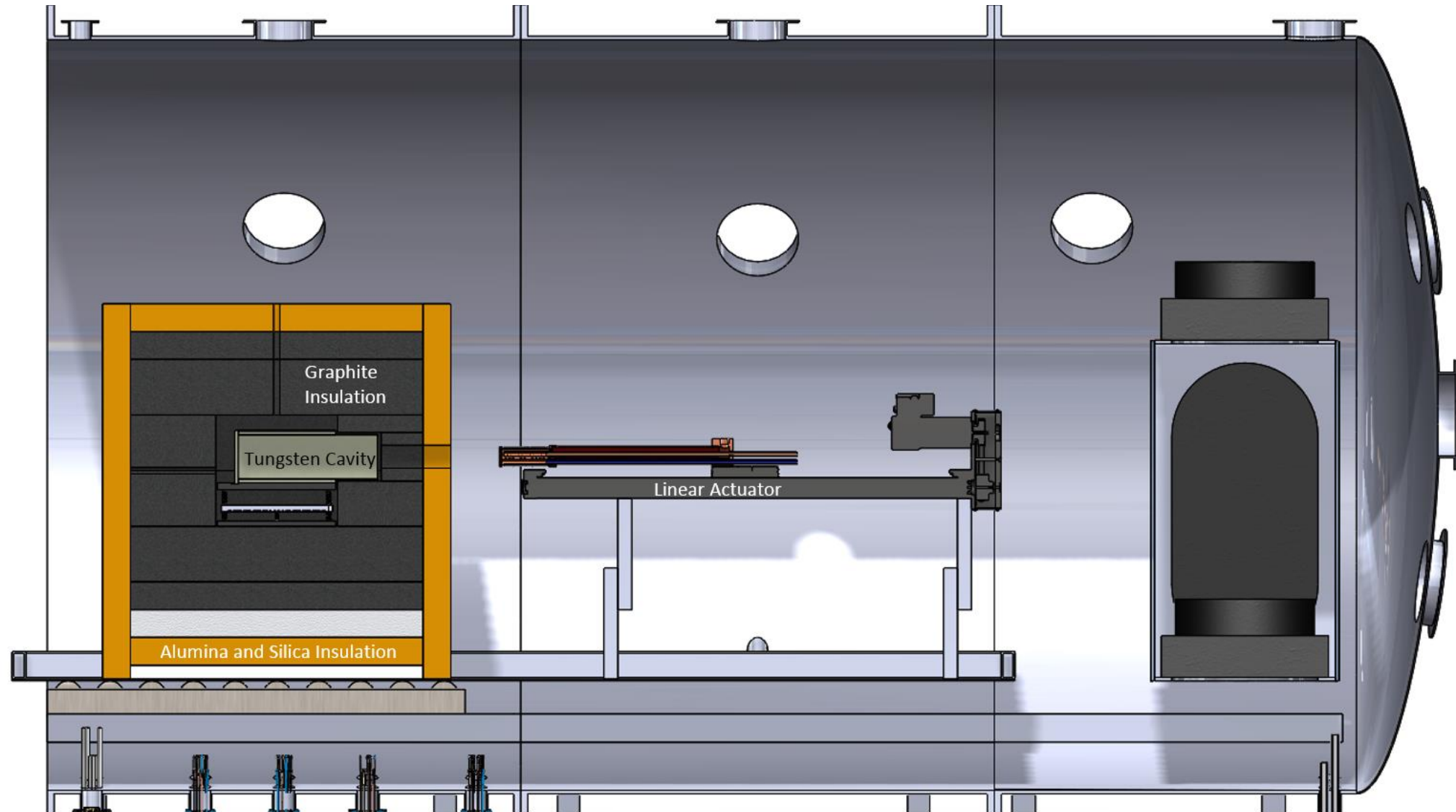


MPV Cells Efficiency

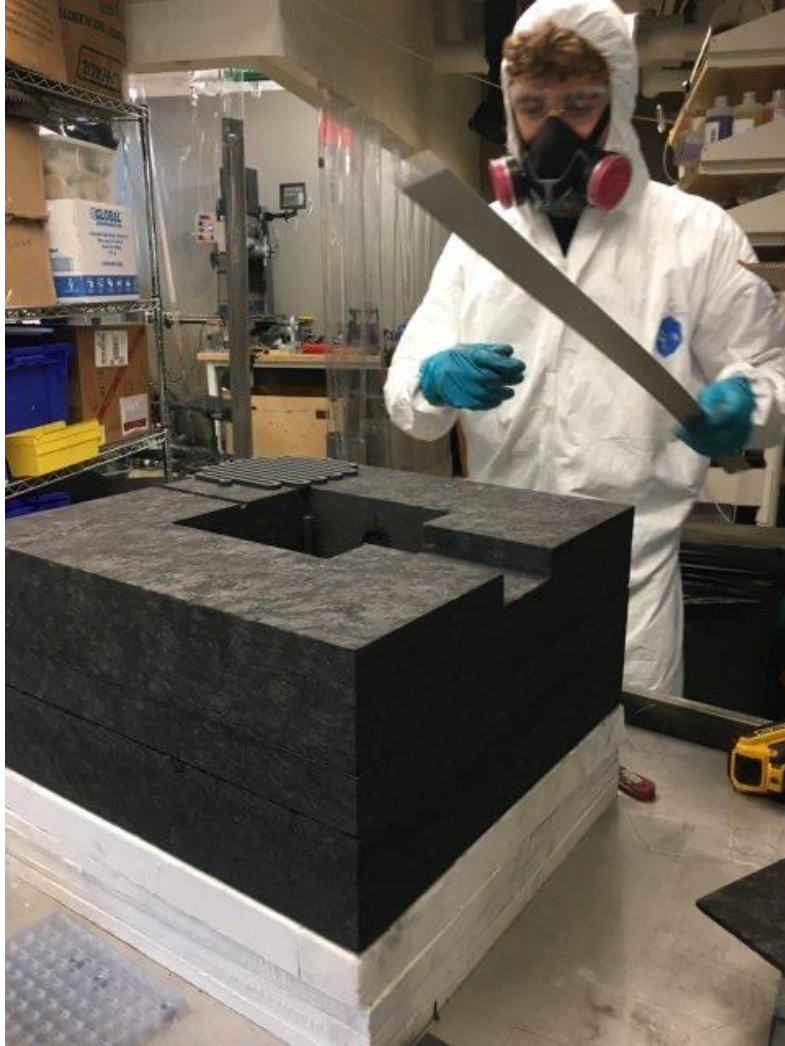
- ▶ Back reflectance measured $\sim 92\%$
- ▶ Peak cell efficiency $\sim 40\%$ (predicted)
- ▶ Limited by series resistance (high current)
- ▶ More optimization of series resistance
- ▶ Thinning and reduction of highly doped layers



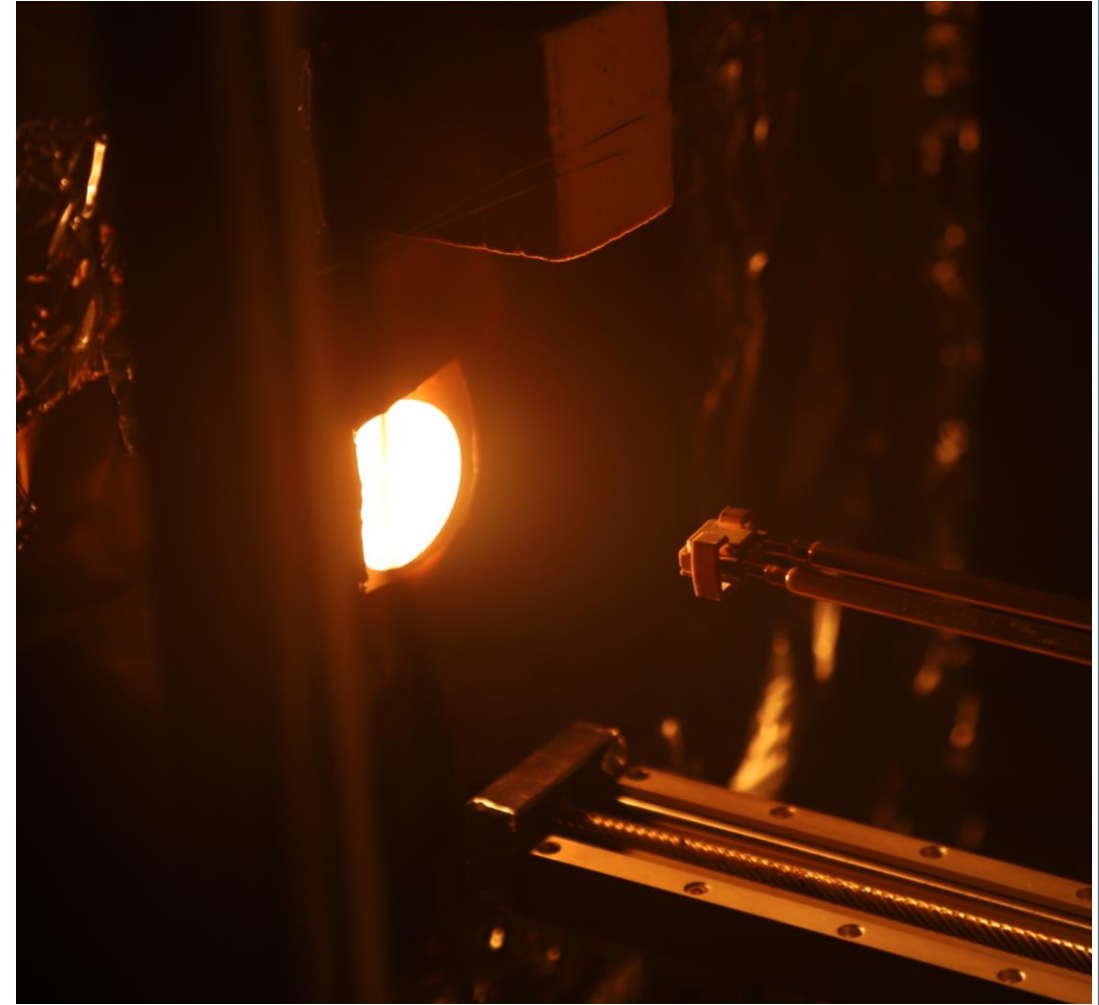
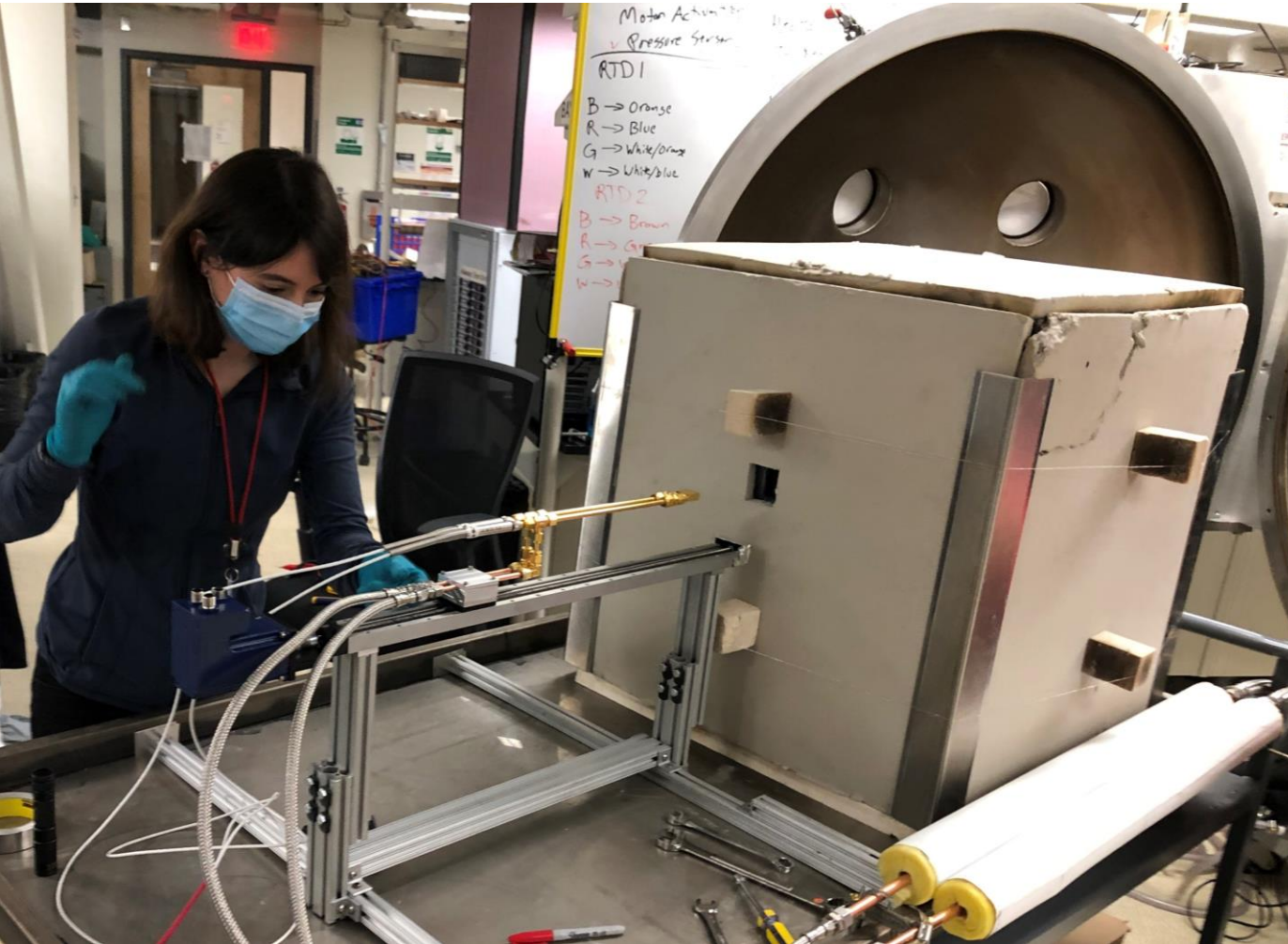
High Temperature Cavity (2150C)



High Temperature Cavity (2150C)

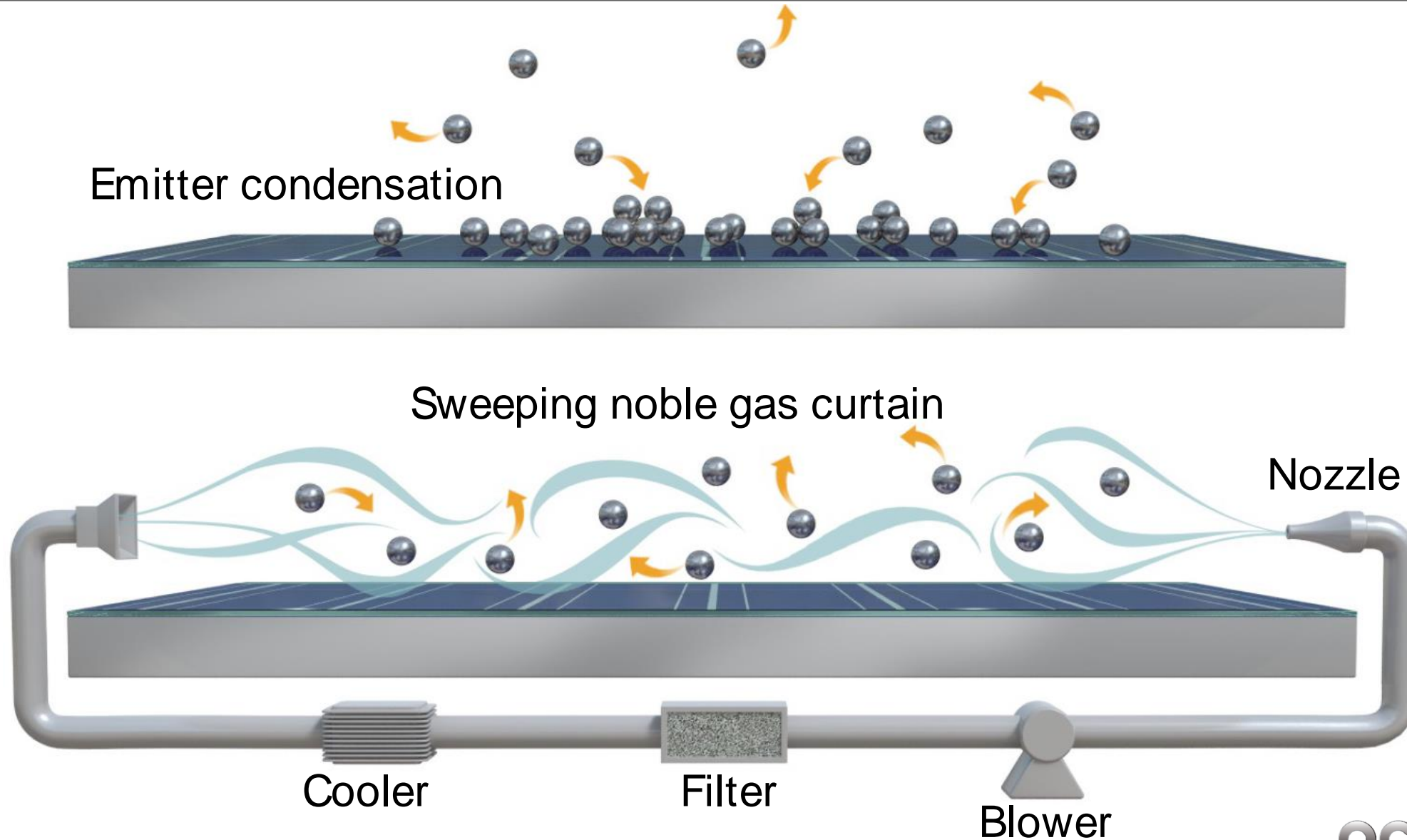


High Temperature Cavity (2150C)



Can control ΔT_{water} from $0.5^{\circ}\text{C} < \Delta T_{\text{water}} < 20^{\circ}\text{C}$ by varying flow rate \rightarrow We can keep the cells cool!

Sweeping Noble Gas Curtain (SNGC)

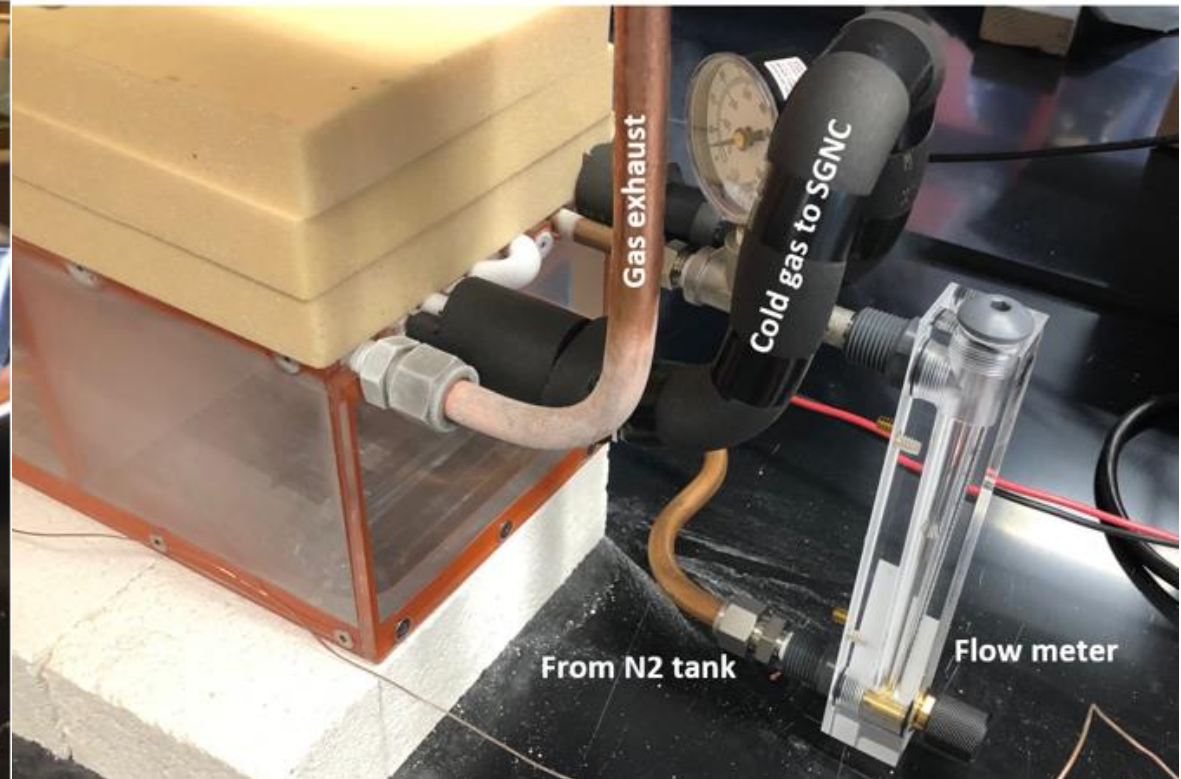


Sweeping Noble Gas Curtain (SNGC)



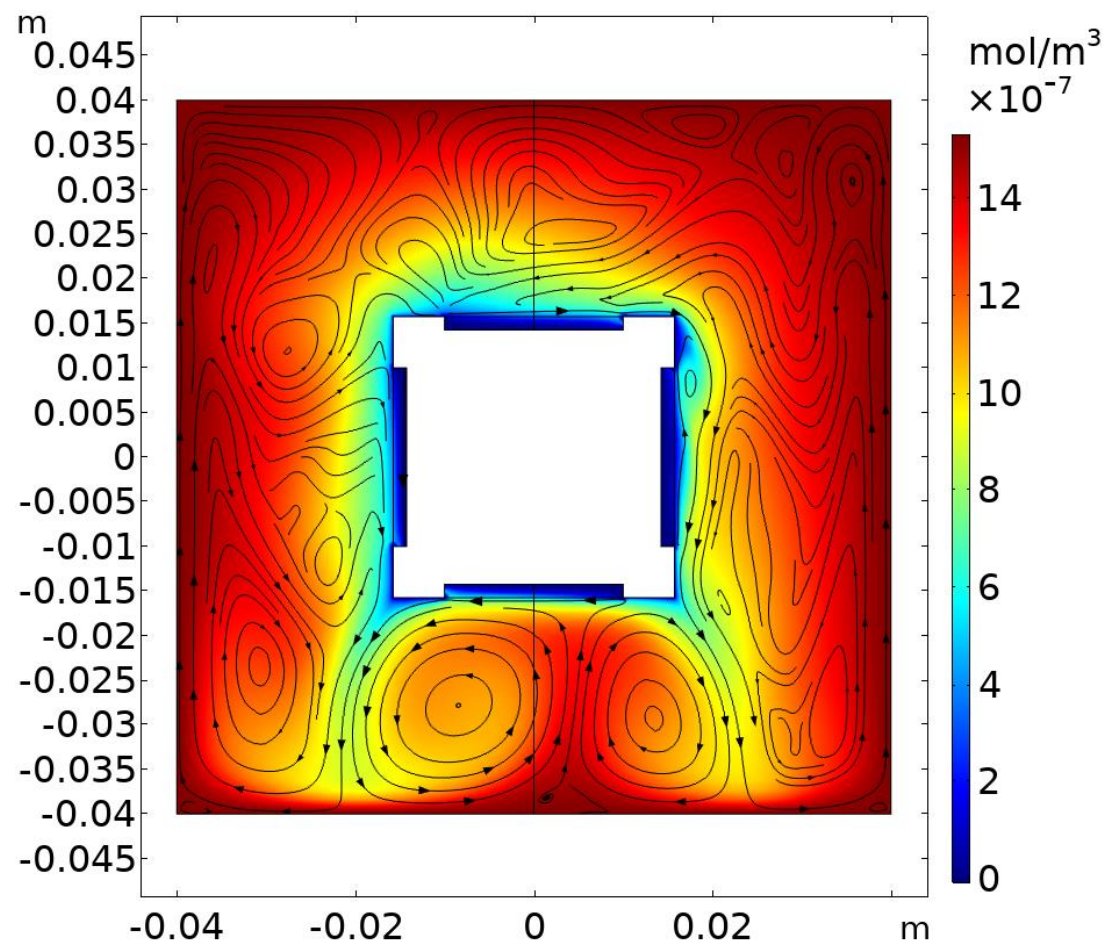
Control Side
Natural
Convection

Testing Side
SNGC
To Prevent Frosting



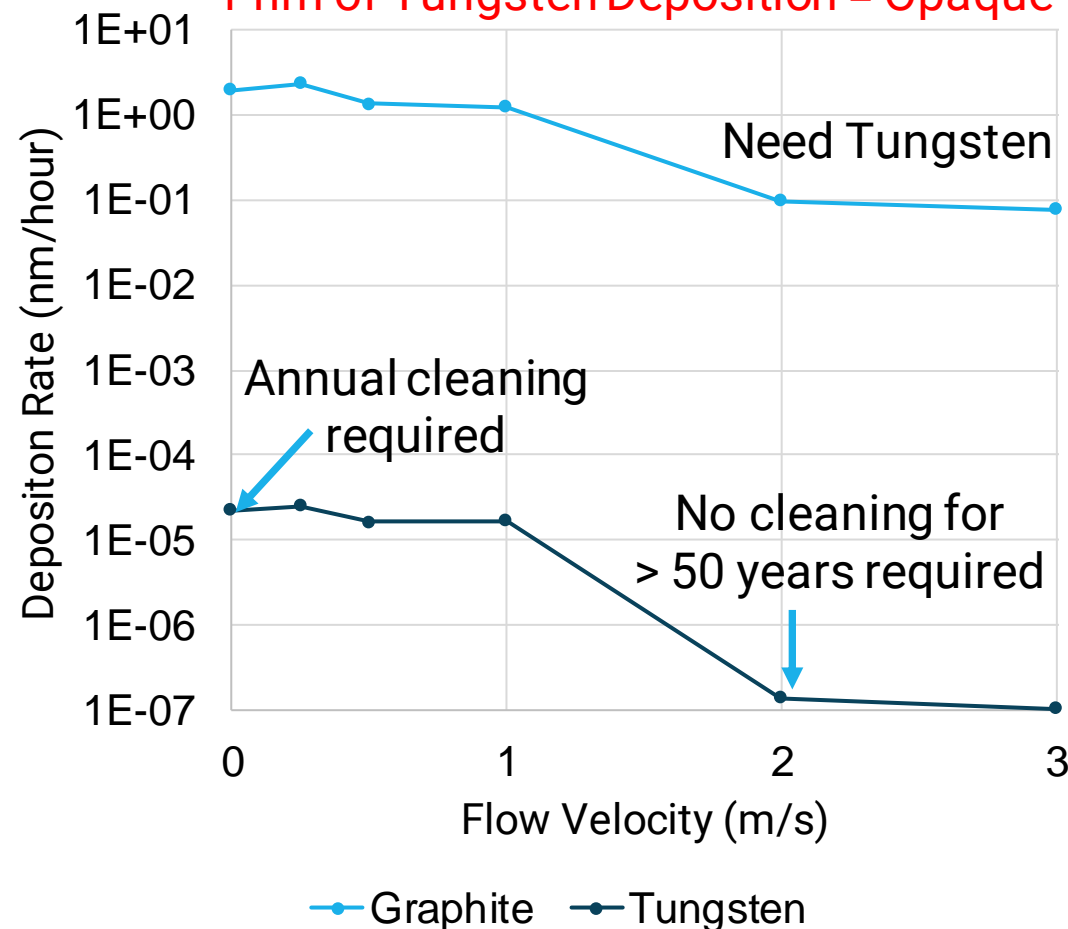
Sweeping Noble Gas Curtain (SNGC)

Example Case
Graphite Emitter
2 m/s flow velocity



Comparison of deposition rates for
graphite and tungsten emitters

1 nm of Tungsten Deposition = Opaque

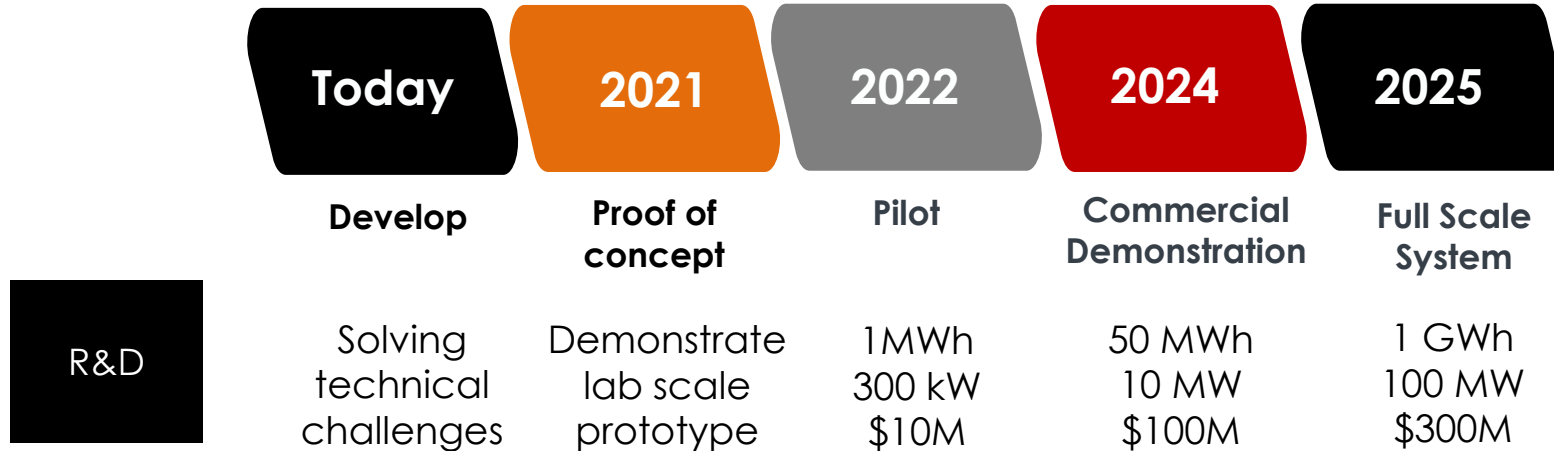


Challenges, Risks and Potential Partnerships

- ▶ Challenges
 - Heating Element Arcing (Solved)
 - Carbon Deposition
 - Wire Bonding
 - Cell Reflectivity
- ▶ Looking to collaborate with cell manufacturers
 - Need more cells
 - Need cell interconnects
- ▶ Can offer expertise on high temperature materials
- ▶ Can offer expertise on high temperature systems



Technology-to-Market



Cost Estimate

Cost per unit energy

$$CPE_{min} = \frac{\text{Cost of the medium}}{\text{Energy Stored} \cdot \text{Roundtrip Efficiency}}$$

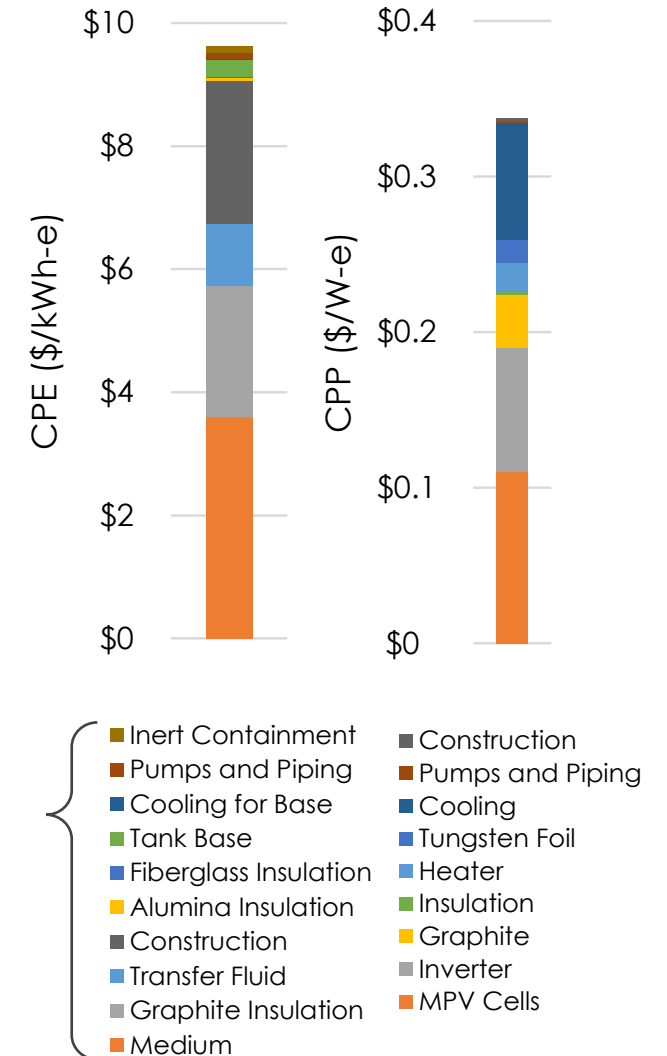
$$CPE_{min} = \frac{[\$/\text{kg}]}{[C_p \cdot (T_{High} - T_{Low}) \cdot RTE]}$$

$$\uparrow$$

$$\$10^{-6}/J = [\$0.5/\text{kg}] \div [2000 \text{ J/kg/K} \cdot (500 \text{ K}) \cdot 0.5]$$

\$3.6/kWh

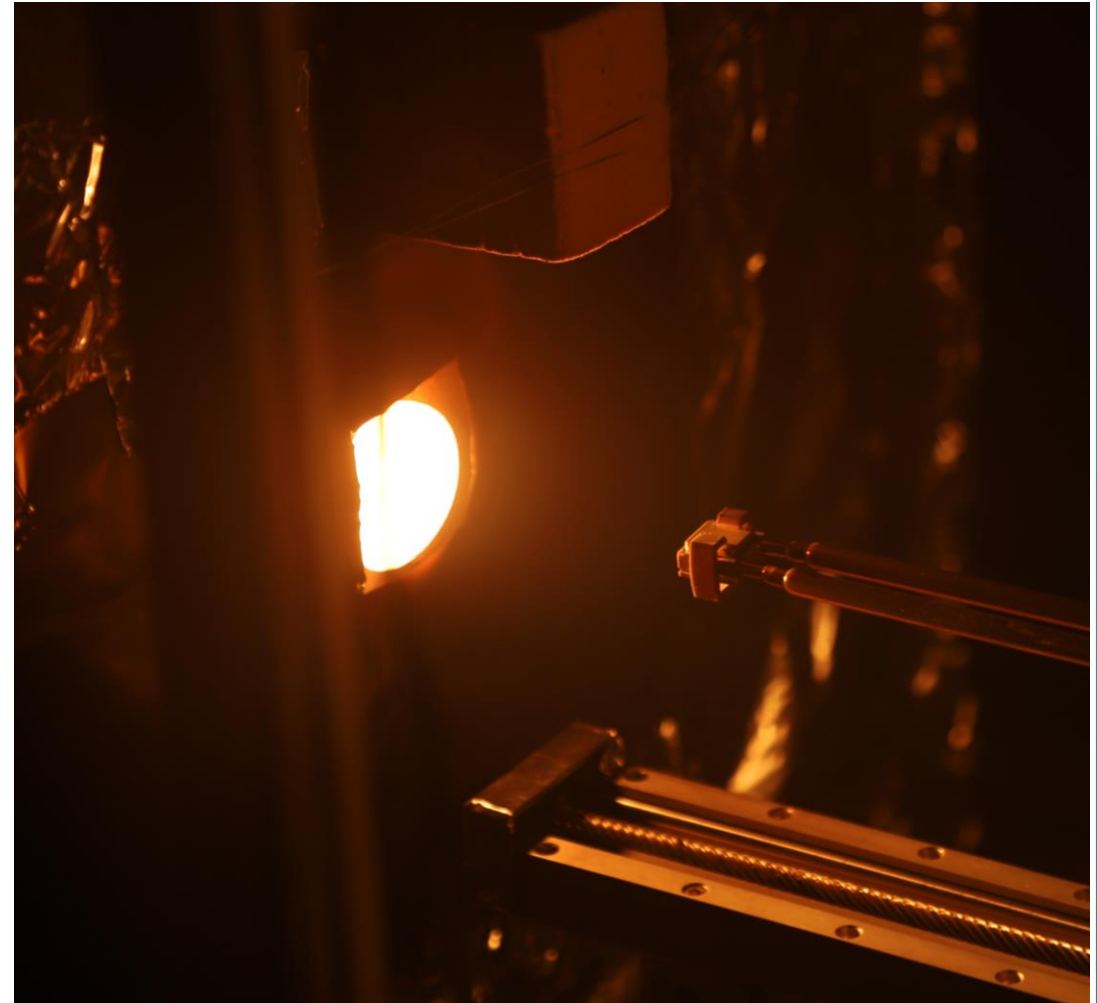
With other system costs added
< \$10/kWh



March 5, 2021

Summary Slide

- ▶ Low cost < \$10/kWh
- ▶ Efficiency target ~ 50%
- ▶ Current efficiency estimate 30-40%
- ▶ Demonstrated ability to keep the cells cool
- ▶ Demonstrated SNGC via proxy (H_2O)
- ▶ Next steps
 - Calorimetric efficiency measurement
 - Mechanical cell connection
 - Solve carbon deposition
 - Demonstrate SNGC in 2150C cavity





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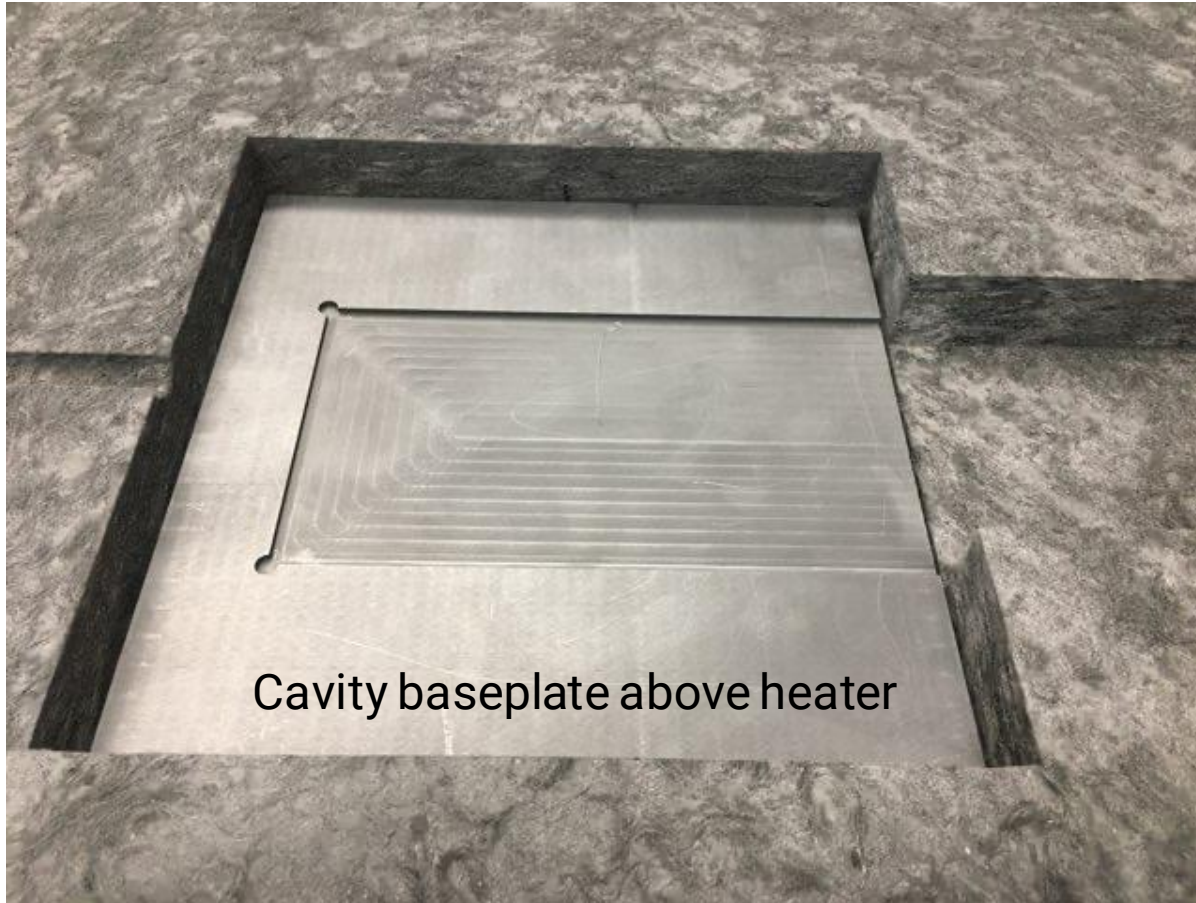
Backup Slides



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High Temperature Cavity (2150C)



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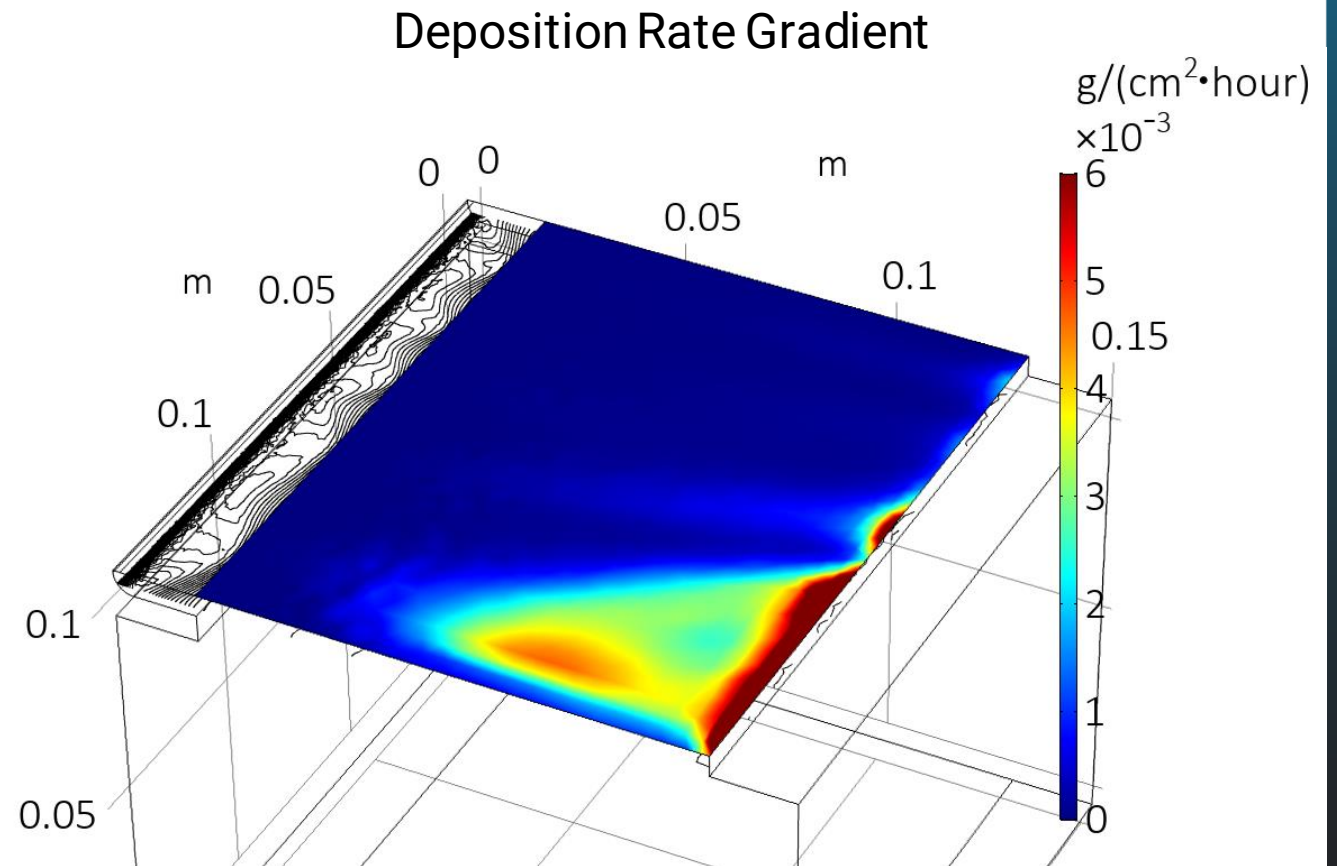


Sweeping Noble Gas Curtain (SNGC)

Experiments



Model Predictions



Challenges, Risks and Potential Partnerships

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